

APR 19 1921

Vol. XIII., No. 5.]

[March, 1920]

PROCEEDINGS  
OF THE  
ROYAL SOCIETY OF MEDICINE

SECTION OF THE HISTORY OF MEDICINE.

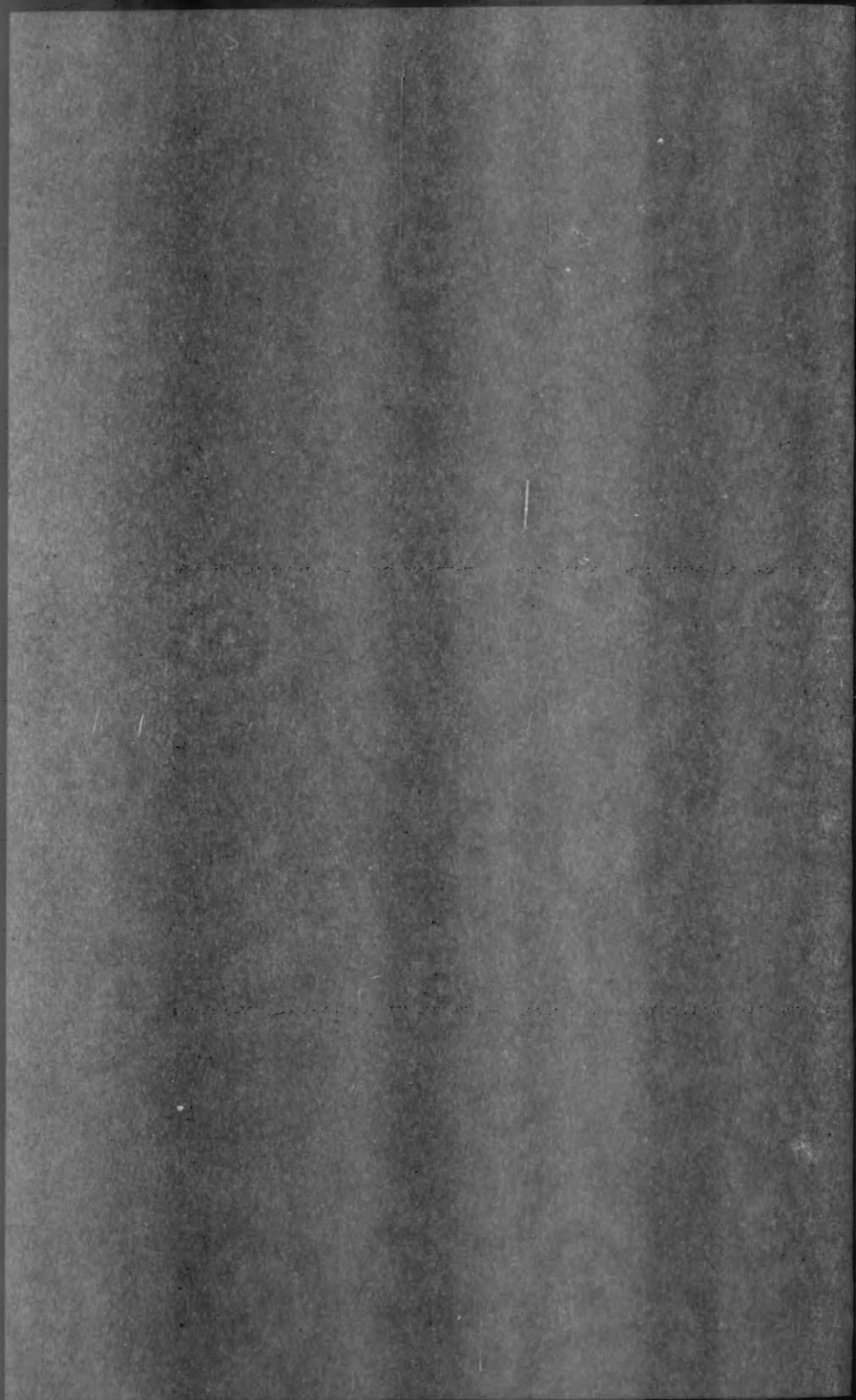
CONTENTS

CRAWFORD DODD, F.R.S.

The Discovery of the Intestinal Protozoa of Man

PAGE

1





Ex

## Section of the History of Medicine.

President—Sir D'ARCY POWER, K.B.E., F.R.C.S.

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### The Discovery of the Intestinal Protozoa of Man.<sup>1</sup>

By CLIFFORD DOBELL, F.R.S.

THE following lines are written with a twofold object: first, to re-direct attention to the discovery of the intestinal protozoa of man; secondly, to correct a mistake—which has already had far too long a life—in the identification of the organisms discovered. At the present moment the intestinal protozoa of man are being much studied and discussed; but the fact that some of them were seen and described nearly two hundred and forty years ago is, if not altogether unknown, at least widely ignored. When it is added that the discovery, whenever mentioned, is almost invariably misunderstood, and consequently cited in a wrong connexion, there seems justification for the belief that a correct account of the whole matter may not be without interest.

It is generally allowed that the free-living protozoa were discovered by the great Dutch microscopist Antony van Leeuwenhoek (1632-1723), who recorded his observations in a famous letter addressed to the Royal Society in the year 1676<sup>2</sup>. But it is not so generally recognized that the same acute observer also discovered the first parasitic protozoa, and recorded his observations a few years later. The organisms were discovered in his own stools, and his description of them is therefore

<sup>1</sup> At a meeting of the Section held December 17, 1919.

<sup>2</sup> The letter is dated 1676, but it records observations made in the previous year and was published in 1677 (*Phil. Trans. Roy. Soc.*, XII, No. 133, p. 821). It was published—but not in full—in English, though it was written in Dutch. The letter is not included in either the Dutch or the Latin collective editions of Leeuwenhoek's works, nor in the "Select Works" translated into English by Hoole. I may add that although this letter is always cited as containing the first description of any protozoa, there is evidence that Leeuwenhoek had observed these organisms even earlier than 1675.

## 2. Dobell: *Discovery of the Intestinal Protozoa of Man*

doubly interesting—being both the earliest record of parasitic protozoa, and, at the same time, the earliest account of the finding of protozoa in man.<sup>1</sup>

Many writers have already mentioned that Leeuwenhoek observed protozoa in his own stools. Few, however, give any reference to the passage in his writings where the discovery was announced : those who give a reference give it wrongly or incompletely ; and nobody appears to have studied his own words with sufficient care to understand them, or with a knowledge of Leeuwenhoek and of the Protozoa adequate to their correct interpretation. The present paper is an attempt to make good these deficiencies.

The observations in question were recorded by Leeuwenhoek in a letter dated 4 Nov. 1681 (N.S.) and addressed to Robert Hooke, at that time Secretary of the Royal Society, of which Leeuwenhoek had recently been elected a Fellow (1680). The letter was presented to the Society by Hooke at a meeting held on November 2, 1681 (O.S.) ; but "being written in Low Dutch, and very long, was referred to the next meeting : and in the mean time Mr. Hooke was desired to procure an English translation of that letter."<sup>2</sup> At the meeting held in the following week (November 9, 1681, O.S.), "Mr. Hooke produced a translation of the long letter lately received from Mr. Leewenhoek, and dated 4 Nov. 1681, N.S. which he read ; containing an account of divers observations and discoveries, which he had lately made concerning great numbers of small animals in his excrements, which were most numerous when he was troubled with a looseness, and very few or none, when he was well."<sup>3</sup>

<sup>1</sup> It seems not unlikely that this work also contains the earliest known reference to the microscopic examination of the stools. It is possible, however, that this had been practised by physicians at a much earlier date. The following remarks by William Molyneux (1692) are of interest in this connexion : " Monsieur Menage a learned and ingenious French-man, in his *Origini della Lingua Italiana, Genevae, 1685*, commenting on the Word *Occhiali del Galilaei*, discourses there of the Time of the invention of *Spectacles* : And . . . he has this notable Passage : That *Monsieur du Cange* had told the Author (*Monsieur Menage*) of a Greek Poem, the Manuscript whereof is now in the *French King's Library*, wherein the Poet, who lived *An. 1150*, Jesting on the Physicians of those Times, says of them to this Purport in *French*, *Qu'ils latent le Poux, et qu'ils Regardent les Excremens du Malade avec une Verre. That they observe the Excrements of their Patients with a Glass. But Mons. Menage is of Opinion, that this was a Transparent Glass, whelm'd over the Vessel, more for the Relief of their Nose against the Stench, than of their Eyes.*" (William Molyneux, "Dioptrica Nova. A Treatise on Dioptricks, &c," Lond., 1692, p. 254.) If the explanation here suggested is correct, then the passage obviously does not refer to the use of a lens, but of a glass plate.

<sup>2</sup> T. Birch : "History of the Royal Society," Lond., IV (1757), p. 99.

<sup>3</sup> T. Birch, *loc. cit.*, p. 101.

It was the custom of the Royal Society to publish letters received from Leeuwenhoek in the *Philosophical Transactions*. As they were written in Dutch—the only language which he could read or write—they were usually “English’d” first, and then published in a more or less abbreviated form. Many of Leeuwenhoek’s discoveries may therefore still be read—albeit in a shortened and old-fashioned English dress—by those who cannot read old Dutch. From time to time, however, Leeuwenhoek himself published his letters in Holland, in the Dutch in which he wrote them; and Latin translations of many also appeared during his lifetime. These were not, of course, translated by himself: nor was he able, owing to his ignorance of the language, to correct faults occasionally committed by his translator. Towards the close of his life his works were issued in two collective editions—“Leeuwenhoek’s Werken”<sup>1</sup> and “Opera Omnia” in Dutch and Latin respectively—neither of them complete, and both of them consisting of several separate parts printed at different times and issued by more than one publisher. Both collections are usually found bound up in four (the Dutch often in five) octavo volumes, and with a pagination and arrangement which make references to individual letters by no means easy. All Leeuwenhoek’s work, it should be added, is in the form of letters addressed to various people; and a large number of the original manuscripts have fortunately been preserved. It will thus be evident that there may be no less than four different versions<sup>2</sup> of any one letter: an original manuscript, in Dutch; a Dutch printed version; a translation of this into Latin; and an English rendering which is often in the form of an abstract.

In the case of the letter with which I am here concerned, all four versions are extant. The original manuscript in Dutch is in the possession of the Royal Society. It was printed in full in a small tract published at Leyden in 1686,<sup>3</sup> and subsequently incorporated in the first volume of the Dutch “Werken.” A complete Latin version of this

<sup>1</sup> Sometimes called “Brieven,” and occasionally “Ontledingen en Ontdekkingen”—the title of the earlier instalments.

<sup>2</sup> There may even, indeed, be five: for Samuel Hoole published a bowdlerized English edition of Leeuwenhoek a century ago, and some of his translations are very good and complete.

<sup>3</sup> The full title is: “Ontledingen en Ontdekkingen Van levende Dierkens in de Teel-deelen Van verscheyde Dieren, Vogelen en Visschen; Van het Hout Met der selver menigvuldige Vaaten; Van Hair, Vlees en Vis; Als mede van de grote menigte der Dierkens in de Excrementen.” Leyden, 1686. A second edition, which differs only in showing some trivial variations in spelling, appeared in 1696.

#### 4 Dobell: *Discovery of the Intestinal Protozoa of Man*

is to be found usually in Vol. I of the so-called "Opera Omnia" (Lugd. Bat., 1722), in the section entitled "Anatomia et Contemplationes"—originally issued separately in 1687. No English version of this letter is to be found in the *Philosophical Transactions*, the publication of which was suspended between 1678 and 1683. During this period, however, Robert Hooke published his "Philosophical Collections," which were virtually a continuation of the *Transactions*: and in No. 4 of these "Collections" (January 10, 1682, pp. 93-98) he printed an English abstract of the letter in question.<sup>1</sup> It has already been noted that the letter was dated November 4, 1681, and addressed to Hooke in person. It should also be noted that it was called by Leeuwenhoek himself his "Thirty-fourth Letter." These marks may help the reader to locate it in the various publications cited; but unfortunately the number of the letter is not always readily ascertainable, and the date was omitted from the Latin version.<sup>2</sup> I may add that only a fragment of the letter—and that not containing the passage I am about to discuss—was translated by Hoole in his "Select Works" of Leeuwenhoek (2 vols. Lond., 1798 and 1807).

After this somewhat lengthy introduction I will now consider the letter itself in detail. It is rather long, and in it Leeuwenhoek discourses in a somewhat disjointed and rambling style—as was his wont—of divers things. The manuscript occupies thirteen pages, closely and neatly written in his own hand. It begins with observations on the structure of hairs, and ends with some remarks upon the gout. The observations upon the intestinal protozoa are introduced incidentally on the way, among various other topics. The passage in question is not long; and as it contains, I believe, all that Leeuwenhoek ever wrote upon this subject, I shall give it in full.

Leeuwenhoek begins by noting that his stools were usually well formed; but as he now and then suffered from diarrhoea, when they became thin and watery, he thought it worth while to examine them under the microscope. Upon doing so he found that they consisted of a clear liquor in which globules of various kinds were suspended. After briefly describing some of these, he proceeds:—

<sup>1</sup> Under the title "A Letter of Mr. Anthony Leuwenhook (sic) dated from Delft, Nov. 4th, 1681. Containing an account of several new Discoveries made by him this last Summer."

<sup>2</sup> I think the shortest and most correct way of citing this letter would be to call it simply "Leeuwenhoek's 34th Letter. To Robert Hooke. 4 Nov., 1681." But the difficulties alluded to above make the foregoing explanations necessary.

" All these described particles lay in a clear transparent medium, in which I have at times seen very prettily moving animalcules, some rather larger, others somewhat smaller than a blood corpuscle, and all of one and the same structure. Their bodies were somewhat longer than broad, and their belly, which was flattened, provided with several feet, with which they made such a movement through the clear medium and the globules that we might fancy we saw a *pissabed* running up against a wall. But although they made a rapid movement with their feet, yet they made but slow progress."<sup>1</sup>

He then makes a few further observations—which will be noted later—on the occurrence of the animalcules, but gives no further description of them. The passage just quoted contains, I believe, all the information available concerning the structure and appearance of the organisms which he observed.

It will be evident that we must first, if we are to discover what these animalcules really were, identify the creature which Leeuwenhoek called a " *pissabed* " : for he compares them with this animal—whatever it may be—and the whole import of the description is lost unless we clearly realize what he had in mind. I have therefore been at some pains to determine this animal's zoological status.

Leeuwenhoek was not a professional zoologist, and systematic zoology was still very uncertain in his day. His names of animals were all popular names—not scientific: and popular names are not very stable or precise. They often denote different organisms at different dates. We therefore want to know what " *pissabed* " meant to Leeuwenhoek—not what it may perhaps mean at the present day.<sup>2</sup> In the hope of getting some information on the subject, I consulted the

<sup>1</sup> This passage, in the original manuscript, runs as follows : " Alle dese verhaelde deeltgens lagen in een heldere doorschijnende materie, in welke heldere materie ik op eenige tijden gesien heb, dat seer aerdig beweegden, dierkens enige wat groter andere wat kleijnder, als een globule bloet, alle van een ende deselvige maecksel, haer lichamen waren wat langer als breed, en haer onderlijf dat platagtig was, met verscheide pooten versien, met de welke sij soo danige beweging door de heldere materie, en globulen maeckten, als of wij ons inbeelden, een pissebedde tegen een muijer te sien op loopen ; en al hoe wel sij een vaerdige beweginge met haer pooten maeckten, soo hadden deselvige nogtans een trage voortgang." The Dutch printed versions (1686, 1696) give this quite faithfully, except for several unimportant differences in spelling and punctuation. The spelling of Dutch at this period was not more uniform and certain than that of Leeuwenhoek's English contemporaries. The printed versions of this passage are in " Werken," I Deel, p. 9 (fourth pagination), and " Opera Omnia," Tom. I, p. 38 (second pagination), of the copies which I use; but the letters are not always bound up in their right order.

<sup>2</sup> I have looked the word up in some modern Dutch dictionaries, but they were not very helpful—zoology not usually being a strong point with the modern dictionary. One such work offered the suggestion that a " *pissabed* " was " a kind of insect " : but somewhat spoilt the definition by adding " belonging to the family of decapod crustacea."

## 6 Dobell: *Discovery of the Intestinal Protozoa of Man*

abstract of this letter in Hooke's "Philosophical Collections." The result was disappointing. The English translator burked the problem by lamely rendering the words in question "like (an animal called in Dutch) a *Pissabed*." I also consulted the Latin version of the letter, hoping that the translator—who must himself have been a Dutchman, and who might be expected to know what animal the name signified—would explain the matter: but he translates the passage "*quasi multipedam per parietem currentem*." This was scarcely more illuminating, since it is difficult to imagine that anyone could compare any of the intestinal protozoa of man with a millepede—which is what "*multipeda*" usually means. I then tried Dutch-English dictionaries of Leeuwenhoek's day, and got what I wanted: for one (1650) told me that a "*pissabed*" is "*a Cheeslip*," and another (1708) said that it is "*a Sow* (a kind of insect)." Now "*sow*" is a name still used in country places to denote the woodlouse (*Oniscus asellus*), and "*cheeselip*" is another old local or popular name for the same animal. I have been able to confirm this interpretation in various ways. An early lexicon<sup>1</sup> in Dutch (both High and Low) and Latin gave me "*Piss-bedde. holl. Asellus, . . . porcellio, . . . multipeda.*" *Asellus* and *Porcellio* are well-known zoological names—both ancient and modern—for woodlice, and "*multipeda*" supplied the clue to the meaning of the word used by Leeuwenhoek's Latin translator.<sup>2</sup> He meant a "*woodlouse*"—not a "*millepede*." Further, Charleton's "*Onomasticon*,"<sup>3</sup> a very early work on zoological nomenclature and belonging to Leeuwenhoek's period, gave me *Asellus*, *Millipes*, *Porcellio*, "*Wood-lowse*," and "*Sow*," as different names for the same animal. My Latin dictionary<sup>4</sup> supplied me with "*cheslip*, *woodlouse*, or *sow-bug*"<sup>5</sup> as English equivalents of *Porcellio*. And finally Dr. Walter E. Collinge—an authority on the British terrestrial Isopods—tells me, in answer to my inquiries, that he has

<sup>1</sup> C. Kilianus: "Dictionarium teutonico-latinum, &c." Antwerp, 1599.

<sup>2</sup> It is perhaps worthy of note that the Isopods seem to have been generally confused with the Myriopods and called by the same names by the ancient writers. Compare Aristotle, *Hist. Anim.*, Lib. V, Cap. 31; Pliny, *Hist. Nat.*, Lib. XXIX, Cap. 6, and Lib. XXX, Cap. 6. Charleton's "*Onomasticon*" (cited below) affords a further instance; cf. pp. 50, 54: and Francis Bacon (*Sylva Sylvarum*, published 1627) refers—under the heading of "Insects"—to "*Millipedes or Woodlice*." The myriopod *Glomeris* is still frequently mistaken for a woodlouse, and may perhaps be partly responsible for the confusion.

<sup>3</sup> Walter Charleton: "*Onomasticon Zoicon, &c.*" Lond., 1668.

<sup>4</sup> E. A. Andrews; "*Latin-English Lexicon*." Lond., 1858.

<sup>5</sup> "*Sow-bug*" is a common name of the woodlouse in the United States at the present day. The comparison of this animal with a little pig is, as will be noted, common to the English and the Latin tongues (*porcellus*, *porcellio*, from *porcus*).

"frequently heard the common woodlouse (*Oniscus asellus*) referred to by lads in the country as 'Pissabed.'"

It is thus clear that Leeuwenhoek compared his animalcules with the little Isopod crustaceans familiarly known to everybody as "woodlice" (*Oniscus asellus* and *Porcellio scaber*). Of this I think there can be no doubt. If we now reconsider his description, it is not difficult to ascertain what the organisms were which he actually saw. He tells us they were very small—of the order of magnitude, approximately, of a human blood corpuscle: that they were rather longer than broad: that they had a flattened ventral surface, on which little feet could be seen moving rapidly: that they resembled little woodlice running on a wall: and finally, that although their feet moved so swiftly, yet the organisms themselves made but slow progression. There is one, and only one, of the intestinal organisms of man which answers to this description: and to anyone familiar with the protozoa of the human bowel, it will, I think, be immediately evident that Leeuwenhoek's description applies to the common flagellate *Giardia intestinalis*<sup>1</sup>—more generally known by the name of *Lamblia*. His description calls up, in fact, a vivid picture of this little animal as seen under a comparatively low magnification. It is a more or less oval organism, convex dorsally but ventrally somewhat flattened or concave, and with its flagella arising chiefly from the ventral surface. The animal is rigid and somewhat compressed dorso-ventrally, and under a low power—especially in side view—is not at all unlike a tiny woodlouse. In the living animal this appearance is greatly enhanced by the movements of the flagella. Even under a low power of the microscope these—particularly the largest mid-ventral pair—are often visible, and their rapid lashing movements simulate the appearance of a row of little feet in active motion. One of the most characteristic movements of this animal, when outside the human body, is a peculiar "skipping" movement. The flagella are lashed violently, but the organism, instead of being propelled forward by them, remains in almost the same spot, jumping up and down. This movement is most noticeable when the flagellate is seen from the side; and it is evidently that to which Leeuwenhoek refers when he says that the motion of the feet was rapid, but progress slow.

From Leeuwenhoek's description it is clear that he must have been observing either a flagellate or a ciliate protozoon. But his organism

<sup>1</sup> Variously known as *Cercomonas intestinalis* Lambl, *Megastoma entericum* Grassi, *Lamblia intestinalis* Blanchard, *Hexamitus duodenalis* Davaine, &c.

## 8 Dobell: *Discovery of the Intestinal Protozoa of Man*

could not have been a ciliate on account of its minute size; and that it was really a flagellate there is every reason to believe, since his account conveys a clear picture of one of the commonest and best known species. There is also some other evidence bearing upon the problem, and this may now be briefly mentioned. In an earlier passage in this same letter, Leeuwenhoek says—as already noted—that his stools were usually normal; and he then gives some further information about himself. He says<sup>1</sup>:

"I have usually of a morning a well-formed stool; but hitherto I have had sometimes a looseness of the bowels in two, three, or four weeks,<sup>2</sup> so that I went to stool some twice, thrice, or four times a day. But this summer [1681] this befell me very often, and especially when I took hot smoked beef, that was a bit fat, or bacon, which food I eat with much enjoyment; indeed, it persisted once for three days, and whatever food I took I retained in my body not much above four hours . . . My excrement being so thin, I was at divers times constrained to examine it [“to observe it,” i.e., under the microscope], and I now, as before, kept in mind what food I had eaten and what drink I had drunk, and what I saw [i.e., afterwards, on examining the stools under the microscope]; but it would take too long to tell all my observations here."

In the foregoing lines there are two points which I wish to emphasize particularly. First, it will be noted that Leeuwenhoek's own words afford no grounds for the inference that he was subject to persistent attacks of diarrhoea.<sup>3</sup> His statements show, in fact, that his stools were generally normal; but that, like most other people, he occasionally had a slight looseness of the bowels which he attributed—and doubtless quite correctly—to dietetic causes. The second point is this. *Giardia* is a protozoon which lives in the small intestine; and therefore its unencysted flagellate forms appear in the stools of an infected person

<sup>1</sup> This is literally translated from the original manuscript, and the Dutch printed versions. The Latin is substantially identical. The words inclosed in square brackets are explanatory, and added by me.

<sup>2</sup> “Somtijds om de 2, 3, à 4. weken heb ik voor desen een dunne doorgang gehad.” Leeuwenhoek's meaning is that he had occasionally had loose stools—roughly, about once or twice a month. He does not mean that he was accustomed to suffer from diarrhoea for periods of two to four weeks at a stretch. The Latin version is ambiguous (“per duas, tres, aut quatuor hebdomadas laxum habui ventrem”), and might be taken in the latter sense—as it has been, apparently, by some readers. The point is of some importance, as will be seen later.

<sup>3</sup> It may be remarked, also, that if Leeuwenhoek had been afflicted with chronic diarrhoea or dysentery we should almost certainly have heard of it. Though he often displays a becoming modesty, he was one of the least reticent of men when engaged in imparting information which seemed to him of scientific interest. The reader who knows his Leeuwenhoek will not need to be reminded of the many passages in which he records personal details such as a modern observer would hesitate to commit to writing.

only under certain conditions—namely, when the small bowel is flushed out. The other common intestinal flagellates of man inhabit the colon, and therefore often appear in the stools of an infected individual when only the lower bowel is emptied. Now Leeuwenhoek tells us that the "animalcules" were present in his stools in circumstances which are precisely those in which *Giardia* would be likely to appear, if he were infected with this flagellate. By microscopic examination he ascertained that his food was passing through him with unusual rapidity, taking "not much above four hours" in the process. A diarrhoea of this sort, in which the small bowel is evacuated, is just what we should expect if our interpretation is correct. Consequently, the conditions recorded harmonize with the identification of his "animalcules" as *Giardia intestinalis*.

Several other points in Leeuwenhoek's letter require notice. He observed—quite accurately, if we suppose that he was infected with *Giardia*—that the organisms varied in numbers in his stools from time to time; and that when his faeces were formed and normal they contained no flagellates,<sup>1</sup> though these reappeared when the diarrhoeic condition recurred. This is what he says:—

"Of these animalcules I saw at one time but one in a [quantity of] material the size of a grain of sand, but again at other times some four or five, or even six to eight. . . . I have also examined my excrement when it was of ordinary consistency, and also mixed with clean water, but could discover therein no animalcules; but whenever the material was somewhat looser than usual, I have, contrary to my expectation, still seen animalcules in it."

These observations contain the germs of two important truths, the establishment of which has taken Leeuwenhoek's successors in this line of work over two hundred years. These are, first, that the numbers of any protozoon found in the stools at any one examination are variable, and therefore afford no certain index of the intensity of the intestinal infection; and secondly, that the organisms may sometimes disappear from the stools altogether, though the infection still persists; and consequently a negative examination is not necessarily an index of non-infection. There is one other feature of Leeuwenhoek's remarks which also deserves notice. It will be observed that although he found "animalcules" in his stools only when they were diarrhoeic, he did not jump to the conclusion that the organisms were the cause of the diarrhoea.

<sup>1</sup> A person infected with *Giardia* passes, of course, only the cysts of this organism in his stools so long as they are solid; and Leeuwenhoek could hardly have distinguished the cysts of *Giardia intestinalis* from other bodies in the faeces.

## 10 Dobell: *Discovery of the Intestinal Protozoa of Man*

He inferred, and doubtless rightly, that the diarrhoea resulted from over-indulgence in certain meats; and that it led to the appearance of the animalcules, to which he apparently attached no importance. In this he showed a degree of good sense vastly above that of many of his successors at the present day.

I think, therefore, that there can be no room for doubt that Leeuwenhoek actually discovered and described the flagellate *Giardia intestinalis*. But he probably saw another flagellate also; for he says, after describing *Giardia*, "I have also once observed animalcules of the same size but of a different structure." Most unfortunately he has left no further account of these, and it would be idle to guess what they may have been.

Having given Leeuwenhoek's own observations in some detail, and having given what I believe to be their correct interpretation, I shall now say something of the construction which has been put upon his findings by other workers. The earliest work that I have seen in which an attempt is made to identify Leeuwenhoek's intestinal "animalcules" is Ehrenberg's big book<sup>1</sup> on the "Infusoria." In this he says<sup>2</sup> :—

"In human intestinal mucus, according to Leeuwenhoek, three species of Infusoria occur, which I have often sought for in vain. He appears to have seen *Vibrio bacillus*, a *Bodo* or monad, and an Acarid (fragment of mucous membrane?)."

I do not know how these remarkable conclusions were arrived at, as no reasons are given. By *Vibrio bacillus* Ehrenberg probably meant the bacteria which Leeuwenhoek described from his stools<sup>3</sup>; and I suppose his "mite" or "bit of mucous membrane"—both impossible interpretations—was the organism (*Giardia*) which Leeuwenhoek compared with a "pissabed." The organism identified with a *Bodo*<sup>4</sup> is, perhaps, the "other animalcule" which Leeuwenhoek says he saw but which he did not describe. Ehrenberg says later in the same work<sup>5</sup> that Leeuwenhoek saw the animalcules in his own faeces in 1684. This also is incorrect; for Leeuwenhoek's letter, as already noted, was written

<sup>1</sup> C. G. Ehrenberg: "Die Infusionsthierchen als vollkommene Organismen." Leipzig, 1838.

<sup>2</sup> *Ibid.*, p. 331.

<sup>3</sup> These were described in the same letter.

<sup>4</sup> No species of this genus, as now understood, is known to occur in the human intestine. But Ehrenberg, who introduced the genus, included in it a very heterogeneous assortment of flagellates.

<sup>5</sup> *Loc. cit.*, p. 521.

in 1681. It will be evident, therefore, that Ehrenberg's remarks on this subject were not particularly happy.

Davaine,<sup>1</sup> in 1860, referred to the fact that the intestinal protozoa of man were discovered by Leeuwenhoek; and he remarks, in discussing the ciliate *Balantidium coli*,<sup>2</sup> that "perhaps one of the infusoria observed by Leeuwenhoek in his own excreta belongs to this genus." A few years later Stein<sup>3</sup> made similar but more definite statements. He expresses the opinion that the organs of locomotion which Leeuwenhoek saw on his animalcules must have been bunches of cilia, and then says:—

"In estimating the size of the animal there must have been a mistake, for, if the animals were not much larger than a human blood corpuscle, it would have been impossible to distinguish the bunches of cilia with the imperfect magnifying glasses then in use. If, however, the animals were considerably larger than Leeuwenhoek states—perhaps only from memory—then his description would apply quite well to *Balantidium<sup>4</sup> coli*."

These remarks have been copied by Leuckart<sup>5</sup> and others, and have been accepted generally by later writers. I shall therefore examine them in some detail.

From Stein's statements it appears that he consulted only the Latin version of Leeuwenhoek's letter, for he cites the "Opera Omnia," and gives a German rendering obviously based upon the Latin text. As noted already, the animal—in reality the woodlouse—with which Leeuwenhoek compared his "animalcules," is called "multipeda" in the Latin translation. Stein renders this "Tausendfuss" in German—evidently mistaking it for a millepede. The organs of locomotion on the animalcules were called by the Latin translator "ungulae,"<sup>6</sup> which Stein translates "Häkchen"—"hooklets" or "claws." But Leeuwenhoek himself said "paws," not "claws." It is therefore not surprising that Stein entirely missed the significance of Leeuwenhoek's comparison, for it is by no means easy to think of any

<sup>1</sup> C. Davaine: "Traité des Entozaires," Paris, 1860.

<sup>2</sup> Called *Paramecium* by Davaine.

<sup>3</sup> F. Stein: "Der Organismus der Infusionsthiere," II Abt., 1867, p. 321.

<sup>4</sup> Stein called this organism *Paramecium coli*.

<sup>5</sup> R. Leuckart: "Die Parasiten des Menschen," II Aufl. (Leipzig u. Heidelberg), 1879, p. 322.

<sup>6</sup> "abdomina unguis multis instructa."

12 Dobell: *Discovery of the Intestinal Protozoa of Man*

intestinal protozoon which resembles a millepede armed with hooklets.<sup>1</sup> But Stein's worst fault is his wholly unjustified assumption that it would have been "impossible" for Leeuwenhoek to have seen anything smaller than a *Balantidium* with his "imperfect magnifying glasses." This shows an ignorance of Leeuwenhoek and his ways of working and his writings which it is difficult to excuse in anybody who pretends to criticize and correct him. It is quite true that he only used "magnifying glasses"—simple lenses, ground and set by himself; but it is doubtful whether anyone has ever surpassed him in the manufacture of these "imperfect" instruments. The proof of their excellence is to be found in the immense number of accurate observations left by their maker. There is no justification whatever for Stein's suggestion that Leeuwenhoek was mistaken in stating that his animalcules were of about the size of a blood corpuscle. Leeuwenhoek had, of course, no micrometers with which to measure accurately the very small objects which he saw: and he was accustomed to gauge their size by comparing them roughly with sand grains, red blood-corpuscles,<sup>2</sup> and other bodies. The human red blood-corpuscle was one of his favourite standards for estimating the magnitude of very small objects; and the modern microscopist, who likes to add to his pictures, for comparison, an outline of a red corpuscle, often unconsciously confirms Leeuwenhoek's choice. It is absurd to say that Leeuwenhoek, who gave the first good comparative account of the blood corpuscles of many different animals; who first described and figured the spermatozoa of a large number of creatures—from insects to human beings; who saw and recognizably described several protozoa much smaller than *Balantidium*; who discovered and first depicted the bacteria and the yeasts;—it is absurd, I say, to assert without a particle of evidence that this man did not estimate the size of his animalcules correctly, or that he supposed a *Balantidium* to be about the size of a red blood-corpuscle! Leeuwenhoek, had he ever seen a *Balantidium*, would probably have described it, in his customary formula, as an animal "a thousand

<sup>1</sup> It may be noted that Leeuwenhoek's statement that his animalcules were flat beneath is omitted altogether by the Latin translator; an omission which does not make the passage more easily intelligible.

<sup>2</sup> Leeuwenhoek was not always so ignorant of the size of small objects as some people appear to think. His "coarse grain of sand" was one having a diameter of approximately  $\frac{1}{5}$  in. (Letter 42); and he states (in the same letter) that a human red blood-corpuscle has a diameter equal to about  $\frac{1}{100}$  of that of a coarse grain of sand—that is, therefore,  $\frac{1}{500}$  in. This is approximately  $8.5 \mu$ —an almost incredibly good estimate. But there is more to be said on this subject; so I will leave it, after merely giving this much in Leeuwenhoek's defense.

times as big " as a red corpuscle. That it would have been "impossible" for him to see any organs of locomotion smaller than a large tuft of cilia is clearly disproved by his records of what he actually did see<sup>1</sup>—whether it be considered possible or not. And finally, Stein's suggestion that Leeuwenhoek was relying for his statements upon a faulty memory seems in no wise justified when it is remembered that Leeuwenhoek—always scrupulously exact in such statements—was actually relating in November what he had observed in the summer and subsequently in the very same year.

There is thus, I think, no evidence whatever to support Stein's belief that the "animalcules" which Leeuwenhoek discovered in his own faeces were *Balantidium coli*. The hypothesis is extremely improbable in any case, apart from any mistranslations and misinterpretations; because *Balantidium* is probably very rare in man in Holland, and there is nothing in Leeuwenhoek's writings to support the view that he was infected with a pathogenic protozoon—a point which has been emphasized on an earlier page. I am not aware, indeed, that a single indigenous case of balantidiosis has ever been recorded in Holland; and as Leeuwenhoek seldom went abroad, and lived for the greater part of the ninety odd years of his life in his native town of Delft, there are no very good grounds for supposing that he ever acquired an infection with *Balantidium*.

As I have already noted, several later writers have copied Stein. Some of them have even gone further. Strong,<sup>2</sup> for example, apparently regards Leeuwenhoek as the first recorded case of balantidiosis. He cites the "Opera Omnia," but apparently relied also upon the statements of Stein and of Leuckart, who merely copied him. Strong begins by saying:—

"Leeuwenhoek . . . reported that when about 30 years old he began to be troubled with loose, painful, and frequent stools. This condition continued for some time and led him to a microscopical examination of his excrement."

If this were so, there might be some justification for supposing that Leeuwenhoek was infected with *Balantidium*. But Leeuwenhoek's words, which Strong translates in this way, are actually as follows<sup>3</sup>:—

<sup>1</sup>The very letter in which the observations in question are to be found also contains a description of bacteria which Leeuwenhoek observed in his own faeces.

<sup>2</sup>R. P. Strong: "The clinical and pathological significance of *Balantidium coli*." *Dept. of Interior, Bur. of Govt. Labs., Biol. Lab. Bull.* No. 26. (Manila), 1904.

<sup>3</sup>The manuscript letter and the Dutch and Latin printed versions all say this. There is nothing in any of them about suffering from painful diarrhoea since the age of 30.

## 14 Dobell: *Discovery of the Intestinal Protozoa of Man*

"I weigh about 160 pounds, and have weighed very nearly the same for about thirty years; and I have usually of a morning a well-formed stool . . ."<sup>1</sup>

Stein's confusion over the locomotory organs of the animalcules becomes worse confounded in Strong's translation. Leeuwenhoek said his animals had "little feet" or "paws"—"pooten": in Latin these became "ungulæ," in German "Häkchen"; but Strong's final version in English tells us that the organisms "moved about with the aid of a little foot-like hook." This is, indeed, a difficult picture to conjure up.

I can find no evidence whatever to show that Leeuwenhoek discovered or described *Balantidium coli*. It is true that Castellani and Chalmers<sup>2</sup> state that "Leeuwenhoek originally discovered the parasite *Balantidium coli*"; and Phillips<sup>3</sup> says, in describing this ciliate, that "the first discoverer of the parasite was Leeuwenhoek, the microscopist, who found it in his own stools during an attack of diarrhoea." But these authors give neither references nor evidence for their assertions. Prowazek,<sup>4</sup> also, has twice told us that Leeuwenhoek probably discovered *Balantidium coli* in his own faeces: and on each occasion he adds, "but its size (a blood corpuscle) was incorrectly estimated." On each occasion also he gives no reference to the passages in Leeuwenhoek's works on which he bases these statements. He gives, however, "*animalcula e stercore ranarum* (Leeuwenhoek)" as a synonym of *Balantidium coli*. Now these "animalcules from the faeces of frogs" are, of course, described in the "Opera Omnia," but they are in a different letter (No. 38, 1683) from that in which Leeuwenhoek's account of the animalcules in his own stools is to be found, and it is difficult to see what connexion they can be supposed to have with *Balantidium coli*—a parasite which does not occur in frogs.

It is interesting to note how Stein's misinterpretations and the errors of later workers finally culminate in Prowazek's assertion that Leeuwenhoek himself was mistaken. Leeuwenhoek did not describe *Balantidium coli*: he described *Giardia intestinalis*. Later workers allege that he described *Balantidium*, but find that his description does

<sup>1</sup>The continuation of this passage has already been given on p. 8.

<sup>2</sup>A. Castellani and A. J. Chalmers: "Manual of Tropical Medicine." Lond., 1913, 2nd ed., p. 1373.

<sup>3</sup>L. P. Phillips: "Amoebiasis and the Dysenteries." Lond., 1915, p. 75.

<sup>4</sup>S. v. Prowazek: "Zur Kenntnis der Balantidiosis." *Arch. f. Schiffs- u. Tropenhyg. (Beih.)*, 1913, xvii, p. 5; and article on "Infusoria-Ciliata," in Prowazek's "Handbuch d. path. Protozoen," 1914, Lief. vi, p. 858.

not fit. Consequently, we now hear that Leeuwenhoek described *Balantidium* incorrectly! Several other recent workers have made similar statements, but I find no indications that any of them have studied Leeuwenhoek's writings for themselves. There is, to my knowledge, but one work in which these observations, when mentioned, are not misrepresented. This is Bütschli's treatise on the Protozoa,<sup>1</sup> in which he says,<sup>2</sup> with his usual good judgement, "It is not probable that the very small animalcules which he [Leeuwenhoek] found in his own faeces during an attack of diarrhoea were Infusoria [= Ciliata]. The description suggests rather that they were flagellates." I will go a good deal further; for I believe not only that flagellates they certainly were, but that it is even possible to determine the species to which they belonged.

From the foregoing pages I think it will appear probable that Leeuwenhoek was the first to observe the intestinal protozoa of man. He recorded his discovery in 1681, and has left a description from which it is possible to identify the organisms discovered. These were flagellates belonging to the species *Giardia* (= *Lamblia*) *intestinalis*: they were certainly not the ciliate *Balantidium coli*, as many writers have stated. The first observations on this latter organism were recorded in 1857 by Malmsten,<sup>3</sup> in Sweden; and he should, consequently, be accredited with the discovery of this human parasite. On the other hand, Lambl,<sup>4</sup> who is now always cited as the discoverer of *Giardia intestinalis*, was forestalled by Leeuwenhoek, whose observations were made about 178 years earlier. And, consequently, the honour of discovering this protozoon belongs in reality not to Lambl and Austria, but to Holland and the Father of Protozoology.

<sup>1</sup>O. Bütschli: "Protozoa," in Bronn's *Klass. u. Ordn. d. Thierreichs.* III Abt., Infusoria, 1887, p. 1101.

<sup>2</sup>According to the bibliographic references given, Bütschli had only read the account in the "Opera Omnia."

<sup>3</sup>P. H. Malmsten: "Infusorien als Intestinal-Thiere beim Menschen." *Arch. f. path. Anat.*, 1857, xii, p. 332.

<sup>4</sup>W. Lambl: "Mikroskopische Untersuchungen der Darm-Excrete." *Vierteljahrsschr. f. prakt. Heilkde.* (Prag), 1859, lxi, p. 1.

